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THz, Infrared and Raman spectroscopies: a powerful combination to study phase transitions in ferroic materials

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The dielectric response of materials is linked to their structure across multiple length scales, involving entities like atomic vibrations, dipoles, polar clusters, domain walls, and domains that respond to electric fields. This response measures charge storage capacity, making it essential to identify key contributors under electromagnetic fields using spectroscopic methods. By selecting frequency ranges, studies can target specific entities, while combining techniques achieves a much broader coverage, even from Hz to 100 THz.

This is especially useful to study materials undergoing phase transitions. Traditional phase transitions fall into displacive types, driven by softening phonon modes that account for dielectric anomalies, or order-disorder types, marked by critical relaxations in the high frequency range (microwave/mm-wave regions) without phonon softening. Many modern materials exhibit mixed transitions featuring central modes—anharmonic vibrations from ion hopping below 1 THz—challenging simple classifications.

Therefore the combination of several probes at different frequency ranges helps to understand the subjacent lattice dynamics and reveals correlations between the different excitations responsible for the properties related to the material structure.